A TEST STRUCTURE FOR DIFFERENTIATING THE LINE AND VIA CONTRIBUTION IN STRESS MIGRATION

FIELD OF THE INVENTION

The present invention relates generally to semiconductor fabrication and more specifically to test structures used to determine stress migration.

BACKGROUND OF THE INVENTION

Stress migration becomes a crucial issue for copper (Cu)/low dielectric constant (low-k) interconnects where a low dielectric constant is less than about 3.0. The usual test structures, such as pull-back (small lower metal with a large top metal), hump (large lower metal with a small top metal) patterns and landed electromigration (EM) patterns, etc., can only give a combination of the line and via resistance shift post stress.

The current best practice is to set up a set of line patterns with the dimensions as close as those in the typical stress migration (SM) patterns. However the result still varies depending upon the position on the wafer and the local pattern density near the test patterns.

U.S. Patent No. 6,342,733 B1 to Hu et al. describes a test structure for EM and SM.

U.S. Patent No. 6,004,827 to Ryan describes various test structures with aluminum runners and overlying dielectrics.

U.S. Patent No. 5,930,587 to Ryan describes an SM method and test structure.

SUMMARY OF THE INVENTION

Accordingly, it is an object of one or more embodiments of the present invention to provide an improved stress migration test structure and stress migration method used to measure and differentiate between line stress migration and via stress migration.

Other objects will appear hereinafter.

It has now been discovered that the above and other objects of the present invention may be accomplished in the following manner. Specifically, a metal line having a middle and opposing first and second ends is formed. First and second opposing pads electrically connected to the respective opposing first and second ends of the metal line through respective first and second step-width line structures are formed. A third pad connected to the metal line proximate its first end by a first via through a first metal structure is formed. A fourth pad connected to the metal line proximate its second end by a second via through a second metal structure is formed. The first and second vias are equidistant from the respective first and second ends of the metal line. The stress migration of the first via is determined by measuring the: sheet resistance between the first pad and the third pad; and/or the stress migration of the second via is determined by measuring the sheet resistance between the fourth pad and the second pad. And the test pattern structure thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be more clearly understood from the following description taken in conjunction with the accompanying drawings in which like reference numerals designate similar or corresponding elements, regions and portions and in which:

Figs. 1 schematically illustrates a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Fig. 1 is a top down, plan view of the test pattern structure 10 of the present invention that is positioned upon a wafer to be tested.

Pad A 20 for Rs (sheet resistance of metal line 28) is connected to Pad D 22 for Rs (sheet resistance of metal line 28) by metal line 28 through respective step-width line structures 24, 26. The step-width line structures 24, 26 each have a greatest width proximate respective Pads A 20, D 22 and a smallest width proximate metal line 28 and are used to prevent extra "two-dimensional effect" (2D effect).

The "2D effect" is when a narrow metal lead is connected to a wide metal. All vacancies in the wide metal will be driven to the narrow metal due to stress gradient. By using a step-case type connection such as in the present invention, e.g. 1/2 reduction in each step, one might reduce the stress gradient and reduce this effect.

Metal line 28 has a width w_1 that is preferably one rule wide. While there is no definite dimension assigned for the test structure of the present invention, one should perform a dimension split for certain technologies to study the design rule.

Pad A/Pad D widths 50/52 are preferably from about50 to 75% wider than metal line 28 width w_1.

Pad B 12 for stress migration (SM) of via 30 is connected to metal line 28 by via 30 through metal structure 16 and Pad C 14 for stress migration (SM) of via 32 is connected to metal line 28 by via 32 through metal structure 18.

Pads B and C are in the same plane and Pads A and D are in the same plane (as they will connect to the top most pads for electrical probing) while metal line 28 is in a different plane from metal structures 16, 18. For example, as shown in Fig. 1, metal structures 16, 18 are in a lower plane than metal line 28 and as such metal structures 16, 18 may be M1 metal layers while metal line 28 may be an M2 metal layer.

This test structure is for interconnect reliability test. The metal lines and holes can be copper (Cu) or an aluminum copper alloy (AlCu). The filling space can be oxide, silicon oxide or another low-k dielectric material. Mainly, this structure is for Cu/low-k material interconnects.

Thus, pads A 20, D 22, B12, C 14 are preferably comprised of Cu or AlCu; step-width line structures 24, 26 are each preferably comprised of Cu or AlCu and are more preferably copper; metal line 28 and metal structures 16, 18 are each preferably comprised of Cu or AlCu and more preferably copper.

As shown in Fig. 1, respective vias 30, 32 have a distance:

l_1 from each other of preferably longer than specific Cu system's Blech Length (it's preferably a copper (Cu) system (grain, stress, dimension, Max force constant density) dependent and is typically greater than 200 to 300 μm) / width w_1 should cover the three range of widths, bamboo or bamboo-like polycrystalline since these various crystalline behavior will affect the performance of the system, these width for the three ranges again is system dependent, typical range would be < 0.25 μm , 0.5 μm , > 1.0 μm.;

l_2 from step-width line structures 24, 26; and

l_3 from Pads B, C.

Preferably:

$l_1 >> l_2, l_3$; and

$w_3 >> w_1$

although the present invention is not limited to these relationships.

One may split various dimension combinations of l_1, l_2 and l_3 for the design rule study.

The width of metal line 28 is usually on-rule, i.e. the smallest dimension of the technology, and w_3 may split for a large range.

The width w_3 of each metal structure 16, 18 is preferably wider than the width w_1 of metal line 28, the on-rule metal line (see above).

As noted above, $w_3 > w_1$ (for upper metal of hump-type) is used for stress migration (SM) test with a larger lower metal and $w_3 < w_1$ is used with a larger upper metal (for pull-back type).

Although the instant invention employs four pads A 20, B 12, C 14, D 22, only two probes (not shown) are contacted to two of the four Pads A 20, B 12, C 14, D 22 to measure the selected parameter, i.e., e.g.:

I. Pad A - D: Line Rs = R_{AD} (Ω (ohm)/square);

II. Pad A - B (or C - D): Single-via 30 (or 32) SM = R_{AB} (or R_{CD}) (Ω);

III. Pad B - C: Dual-via 30, 32 SM = R_{BC} (Ω); and

IV. If $w_3 >> w_1$, then:

Via 30, 32 Rc = R_{AB} (or R_{CD}) - (R_{AD} * l_2 (number of squares)), or

Via 30, 32 Rc = (R_{BC} - (R_{AD} * l_2))/2

The total sheet resistance of metal line 28 is:

$R_{AD} = Rs_{AD} * (l_1 + 2l_2)$ (number of squares on the metal line)

For example, the total resistance of the test pattern from:

Pad A to Pad B is $R_{AB} = Rs_{AD} * l_2 + Rc\ (30)$;

Pad C to Pad D is $R_{CD} = Rs_{AD} * l_2 + Rc\ (30)$; and

Pad B to Pad C is $R_{BC} = Rs_{AD} * (l_1 + 2Rc(30 + 32)$

when $w_3 >> w_1$ and where l_1 and l_2 are in number of squares. If w_3 is not >> w_1 then l_3 in number of squares must be added to l_2 at each instance.

The test pattern structure 10 formed in accordance with the instant invention may be used to, for example:

(A) dimension split for rule check (can create design rule) – some examples are:

1) metal dimension (w_3 X l_3) connect to via or necessary to implement dual via structure; and

2) critical metal length at w1 line;

(B) process optimization with high sensitivity chain structure – use 10, 500 or much more units to test the yield since the failure rate will increase with more units;

(C) study 3D stress migration effect – i.e. where a via is pulled back in stress migration (SM) and a void causes an open failure; and

(D) can determine the contribution from lines or vias – by previous calculation (see above), the line and via resistance can be differentiated so the contribution of resistance shift by stress migration (SM) can be identified as coming from metal lines or vias;

and

(E) can be used for process optimization in advanced process development and design rule setup for interconnects.

If one knew the contribution from the line or via, one may optimize the trench process or via process respectively. This is the point of process optimization.

Advantages of the Present Invention

The advantages of one or more embodiments of the present invention include:

1. the conventional stress migration (SM) resistance shift can be measured with both line and via resistance by Pads A, D; and

2. by using different line dimensions, the Rs contribution from the upper or lower metal line can be determined in a more realistic way so that the component of resistance shift is differentiated.

While particular embodiments of the present invention have been illustrated and described, it is not intended to limit the invention, except as defined by the following claims.